Energy Storage R & D Efforts

Presented to

The Plug-in Hybrid Vehicle Forum
at
The Air Quality Management District Headquarters

By

Tien Q. Duong
FreedomCAR and Vehicle Technologies Program
U.S. Department of Energy

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- Thoughts on PHEV Batteries

Mission and Goals

Mission

Conduct research and development on electrochemical energy storage technologies which support the commercialization of hybrid electric vehicles

Goals

- By 2010, develop an electric drivetrain energy storage system with 15-year life at 300 Wh, with discharge power of 25 kW for 18 seconds, and $20/kW
- Draft Goal – By 2014, reduce the cost of PHEV batteries to $300/kWh

Budget

	FY 06 ($k)	FY 07 Request ($k)	Part of FY 07 Request for Plug-Ins ($k)
High Power Energy Storage	**16,720**	**17,181**	
High Energy Battery Development	**1,443**	**7,615**	**6,172**
Focused Fundamental Research	**6,279**	**6,343**	
Total Energy Storage	**24,442**	**31,139**	
Technologies Relevant to Plug-In HEV			
Advanced Power Electronics	12,895	13,680	2,000
Simulation and Validation	3,175	6,729	2,750
Vehicle Test & Evaluation	2,475	3,484	1,000

Program Structure

High Power Energy Storage

- Develop electrochemical energy storage devices that meet FreedomCAR HEV goals

High Energy Battery Development

- Benchmark candidate and emerging technologies
- New Request in FY 2007: Plug-in hybrid battery development

Focused Fundamental Research

- Conduct innovative, cutting-edge long term research on the next generation of lithium battery systems

Developer Program

Develop electrochemical energy storage devices that meet USABC/FreedomCAR technical goals

- United States Advanced Battery Consortium (USABC) is a partnership among DaimlerChrysler, Ford, and General Motors formed in 1991 to foster the development of advanced batteries
- Develop full battery systems through competitive subcontracts with the USABC
  - » Performance targets developed through modeling and simulation
  - » Candidate technologies benchmarked before full-scale development
  - » All contracts require a minimum cost-share of 50%
- USABC deliverables tested and analyzed against performance targets using standardized test procedures

Applied Research

A multi-laboratory effort assisting battery developers to overcome performance barriers associated with high-power Li-ion battery technology

Focus

- Understand, extend, and more accurately predict **battery life**
- Search for and develop **low-cost** cell materials and components
- Understand factors that affect **abuse tolerance**
- Understand factors that limit **low-temperature performance**

High Energy Battery Development

In FY 2007

Request of $6.172 Million Increase for Plug-in Hybrid Electric Vehicle (PHEV) Battery Development

(An addition to funding levels and R&D efforts of previous years)

- Develop PHEV battery performance requirements in collaboration with US auto companies
- Benchmark and assess promising higher energy battery technologies
- Initiate research and development programs to address performance gaps
- Plan to issue solicitation in Fall 2006 through USABC

Focused Fundamental Research

A multi-laboratory and university effort to conduct innovative, cutting-edge research on the next generation of lithium battery systems

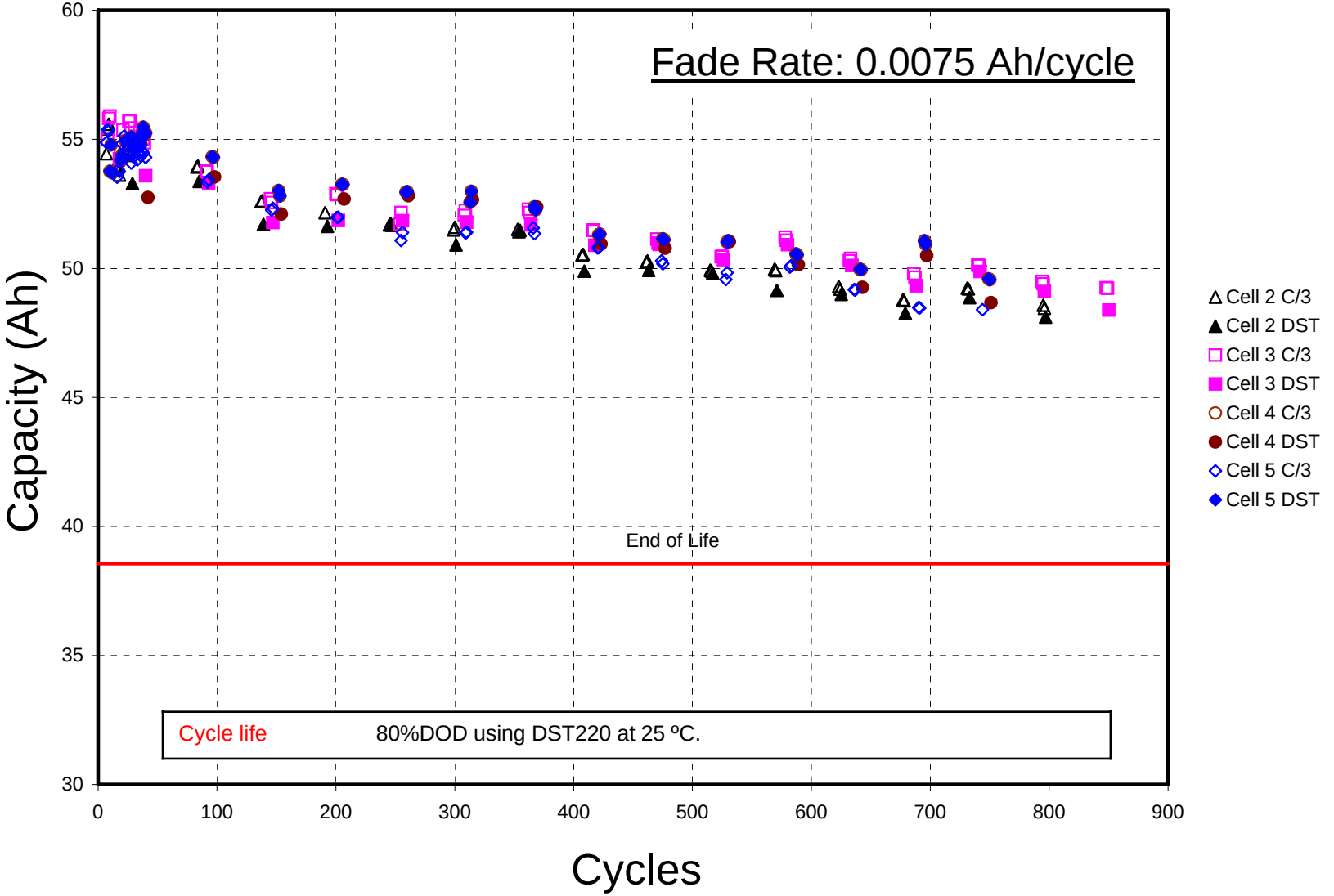
- Focused investigations on novel materials (cathode, anode, electrolyte) that promise greatly increased power and energy
- Develop and apply advanced electrochemical models
- Employ advanced diagnostic tools to investigate failure mechanisms
- Coordinate research effort with the DOE Office of Science and National Science Foundation

Current Research Emphasis

- Anodes
  - Develop novel inter-metallic alloys and new binders to accommodate their volume change
  - Investigate nanophase metal oxides
- Electrolytes
  - Development of high voltage electrolytes (4.5 – 5 Volts)
  - Development of electrolyte additives to improve interfacial stability
  - Development of solid polymer electrolytes with improved conductivity and mechanical strength
- Interphase studies
  - Continue to search for better membrane or glasses to stabilize the surface of a metallic lithium anode

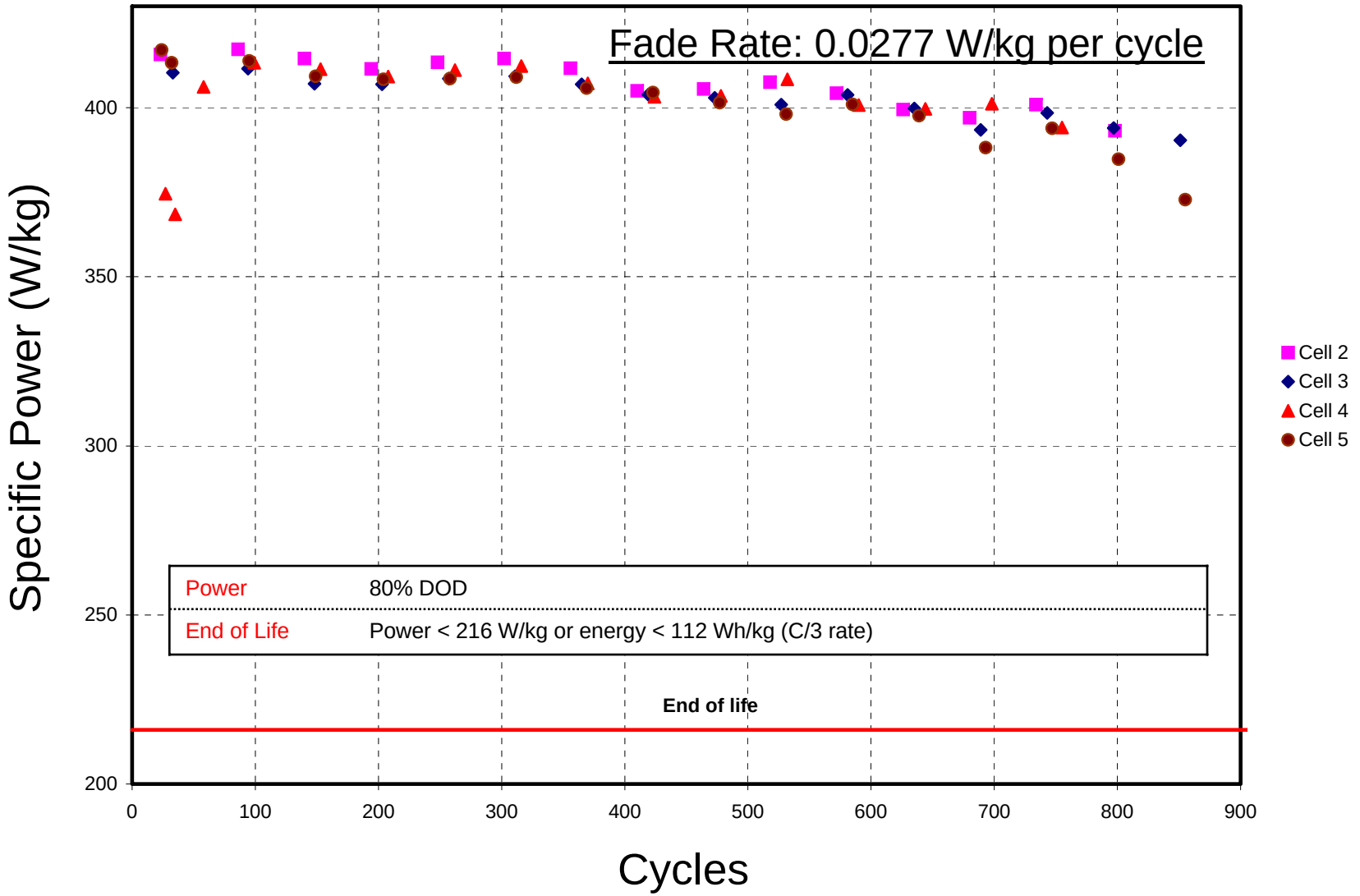
SAFT High Energy Lithium-ion 47.5Ah Cells

Capacity Fade over Number of Cycles



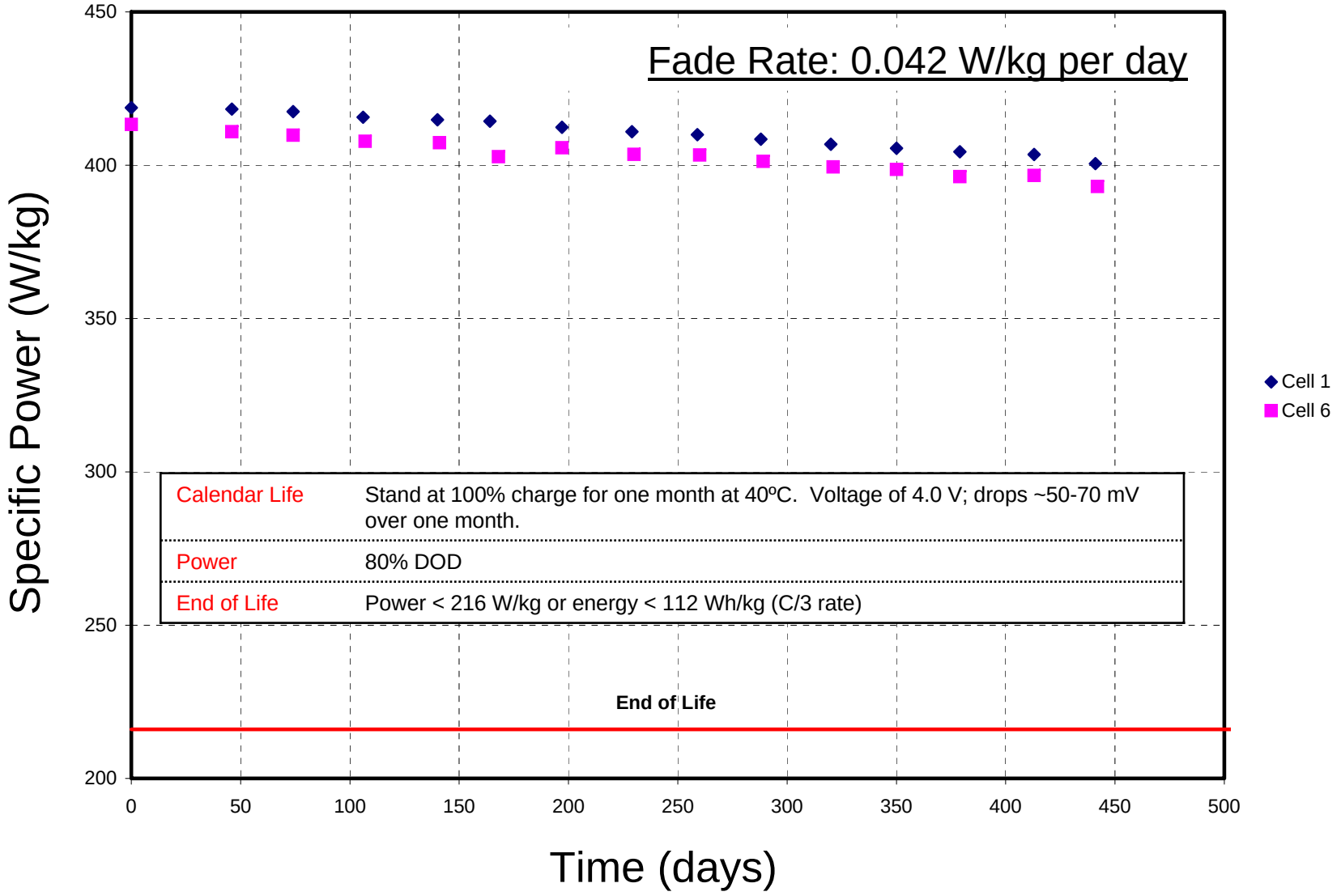
SAFT High Energy Lithium-ion 47.5Ah Cells

Power Fade over Number of Cycles



SAFT High Energy Lithium-ion 47.5Ah Cells

Power Fade over Calendar Life Test



Hybrid Electric Vehicles

- Development status of lithium-ion batteries for power-assist HEVs is about where NiMH was in 2000
- Major focus is on cost reduction
  - Abuse tolerance and performance at low temperatures are still issues
    - » New electrode materials ($Li_4Ti_5O_{12}$, $LiFePO_4$) now under development appear to address these two issues
  - Batteries, even those incorporating “stable” materials, will require appropriate thermal controls and electronic protection circuits to extend battery life and avoid thermal runaway
  - Battery life projections of 15 years are based on limited data.

Electric Vehicles

- Current battery technologies limit a vehicle's range on single charge to a value significantly less than 300 miles
- Cost increases with the size of the battery
  - Metallic lithium systems (150 Wh/kg) offer a longer range, but poor cycle life
  - Most lithium-ion systems are limited to 100 Wh/kg
    - » Cathode materials being considered are capacity-limited
    - » Batteries are power-limited, especially at 80%DOD after many cycles
    - » Most lithium systems can not accommodate fast charge
    - » Batteries sitting at high SOC experience reduced calendar life

My Thoughts on PHEV Batteries

- Certainly a viable technology
  - Cost is a potential show stopper
- Development of PHEV batteries benefits from lessons learned during HEV and EV battery development – lot of synergies
  - Impact of dual mode of operation (electric only and power assist) on battery life is not understood
    - » Battery life may be extended if the engine were to provide power assistance, if needed, during the charge depleting portion of operation
    - » Operation at a less extreme “sweet spot” (i.e., 30-40% SOC) would extend battery life

Thank you for your support of the DOE Energy Storage R&D effort